



Faculty of Engineering

**CONVERSION AND CHARACTERIZATIONS OF
BIODIESEL BY TRANSESTERIFICATION
OF OLIVE OIL**

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
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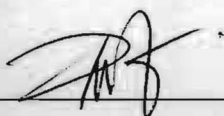
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**CONVERSION AND CHARACTERIZATIONS OF BIODIESEL BY
TRANSESTERIFICATION OF OLIVE OIL**

WONG LEH FENG

Thesis is submitted to
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Dedicated to my beloved family and friends, who always bestow me sustainable
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ABSTRACT

The consumption of petroleum is increasing ceaselessly in the world. The awareness on depletion and detrimental environmental concerns of fossil fuels has been stimulating the growth of renewable liquid fuel. Vegetable oil has been emerging as the potential substitute of diesel, but it has to be modified into biodiesel to produce its combustion properties closer to those of diesel. In this study, base-catalyzed transesterification was used to derive the biodiesel from olive oil with the presence of methanol and potassium hydroxide (KOH) catalyst under microwave heating. The optimal reaction time was 6 min with total yield of 88%, while the further increase of reaction time led to the reduction of end product. The thermal stability, density, and flash point of the biodiesel were also analyzed. Biodiesel at 9 min reaction time had the highest thermal stability, while biodiesel at 4 min showed the poorest thermal stability. As compared to diesel, biodiesel had greater thermal stability. Thus, biodiesel mixing to diesel made the fuel more stable against heat, as well as to lower the density of the biodiesel in order to meet the ASTM D1298. B20 and B50 had met the ASTM D1298, but their thermogram showed that they are not mixed homogeneously. In contrast, B80 showed the better mixing. Lastly, the flash point of pure biodiesel and biodiesel blends ($> 220^{\circ}\text{C}$) are higher than diesel (81°C).

Keywords: Biodiesel; Base-catalyzed transesterification; Olive oil; Reaction time; Thermal Stability, Density; Flash point

ABSTRAK

Penggunaan petroleum di dunia telah meningkat secara berterusan. Kesedaran terhadap kekurangan dan pencemaran alam sekitar masalah daripada bahan api fosil telah merangsang perkembangan sumber bahan api cecair yang boleh diperbaharui. Minyak sayur telah muncul sebagai pengganti diesel yang berpotensi., tetapi ia perlu diubah suai menjadi biodiesel supaya ciri-ciri pembakarannya lebih menyerupai diesel. Dalam kajian ini, alkali-pemangkin transesterifikasi telah digunakan untuk memperolehi biodiesel daripada minyak zaitun dengan kehadiran metanol dan pemagkin kalium hidroksida (KOH) di bawah mikro pemanasan. Masa tindak balas optimum adalah 6 min dengan jumlah hasil sebanyak 88%, manakala peningkatan lagi masa tindak balas membawa kepada pengurangan produk akhir. Kestabilan haba, ketumpatan dan titik flash biodiesel juga telah dianalisis. Biodiesel pada 9 min masa tindak balas mempunyai kestabilan haba yang tertinggi, manakala biodiesel pada 4 min menunjukkan kestabilan haba yang paling teruk. Berbanding dengan diesel, biodiesel mempunyai kestabilan haba yang lebih bagus. Oleh itu, campuran biodiesel kepada diesel menjadikan bahan api lebih stabil terhadap haba, serta untuk merendahkan ketumpatan biodiesel bagi memenuhi ASTM D1298. B20 dan B50 telah memenuhi ASTM D1298, tetapi termogram mereka menunjukkan bahawa mereka tidak bercampur homogeneously. Sebaliknya, B80 menunjukkan percampuran yang lebih baik. Akhirnya, titik flash biodiesel tulen dan campuran biodiesel ($> 220^{\circ}\text{C}$) adalah lebih tinggi daripada diesel (81°C).

Keywords: Biodiesel; Alkali-pemangkin transesterification, Minyak zaitun; Masa tindak balas; Kestabilan haba; Ketumpatan; Titik flash

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LIST OF ABBREVIATIONS

| | |
|--|--|
| ASTM | American Society for Testing and Materials |
| Al ₂ O ₃ | Aluminium oxide |
| Al ₂ O ₃ /KI | Aluminium oxide/Potassium iodide |
| B_4, B_5, B_6, B_7, B_8, | Biodiesel at 4, 5, 6, 7, 8, 9 min reaction times |
| B_9 | |
| B00, B20, B50, B80, B100 | Biodiesel at 0%, 20%, 50%, 80%, 100% blending ratios |
| BaO | Barium oxide |
| C14:0 | Myristic acid |
| C16:0 | Palmitic acid |
| C18:0 | Stearic acid |
| C18:1 | Oleic acid |
| C18:2 | Linoleic acid |
| C18:3 | Linolenic acid |
| CaMnO ₃ | Calcium manganese oxide |
| CaO | Calcium oxide |
| CaO–CeO ₂ | Calcium oxide-cerium oxide |
| CaTiO ₃ | Calcium titanate |
| CaZrO ₃ | Calcium zirconate |
| Ca ₂ Fe ₂ O ₅ | Srebrodolskite |
| CEN | European committee for standardization |
| CH ₃ O [•] | Methoxy radical |

| | |
|------------------------------------|---------------------------------------|
| CO | Carbon monoxide |
| CO ₂ | Carbon dioxide |
| DG | Diglyceride |
| DTA | Differential Thermal Analysis |
| EN | European |
| Eq. | Equation |
| ETS-10 zeolite | Ethylene on titanosilicate-10 zeolite |
| GHG | Greenhouse gas |
| HC | Hydrocarbon |
| K ⁺ | Potassium ion |
| KNO ₃ | Potassium nitrate |
| KOH | Potassium hydroxide |
| KOH/Al ₂ O ₃ | Potassium hydroxide/Aluminium oxide |
| K ₂ CO ₃ | Potassium carbonate |
| max | Maximum |
| MG | Monoglyceride |
| MgO | Magnesium oxide |
| MSW | Municipal solid waste |
| Na ⁺ | Sodium ion |
| NaOH | Sodium hydroxide |
| NaOCH ₃ | Sodium methoxide |
| Na ₂ SO ₄ | Sodium sulphate |
| R | Hydrocarbon group |
| RCOOR ₁ | Ester |
| ROH | Alcohol |

| | |
|--------------------|---|
| SrO | Strontium oxide |
| TG | Triglyceride |
| TGA | Thermogravimetric analysis |
| TGB | Third generation biofuels |
| T90 AET | Temperature 90% recovered; Atmospheric equivalent temperature |
| FAME | Fatty acid methyl ester |
| FFA | Free fatty acid |
| FGB | First generation biofuel |
| SGB | Second generation biofuels |
| ZnO/I ₂ | Zinc oxide/Iodine |

LIST OF NOMENCLATURE

| | |
|----------------------|-----------------------------|
| % | Percentage |
| °C | Degree celsius |
| °C/min | Degree celsius per minute |
| °F | Fahrenheit |
| b/d | Barrels per day |
| Btu/gal | British thermal unit/Gallon |
| cSt | Centistokes |
| g | Gram |
| g/cm ³ | Grams per centimeter cubed |
| g/mol | Grams per mole |
| h | Hours |
| kg | Kilogram |
| kg/L | Kilogram per liter |
| kg/m ³ | Kilogram per meter cubed |
| kPa | Kilopascal |
| lb/gal | Pound per gallon |
| L | Liter |
| mg/kg | Miligram per kilogram |
| min | Minute |
| mL | Milliliter |
| mL min ⁻¹ | Milliliter per minute |

| | |
|--------------------|------------------------------|
| mm ² /s | Square millimeter per second |
| M | Molar |
| MPa | Megapascal |
| MJ/kg | Megajoules per kilogram |
| rpm | Revolutions per minute |
| s | Second |
| V _{avg} | Average volume |
| V _T | Total volume |
| vol. % | Volume percentage |
| wt. % | Weight percentage |
| W | Watt |

CHAPTER 1

INTRODUCTION

1.1 Overview

The world primary energy consumption grew by 2.5% in 2011 where oil remains the world's leading fuel at 33.1% of global energy consumption (BP, 2012). The world oil production had reported to increase by 1.3% in 2011, meanwhile the world oil consumption increased by 0.7% as compared with 2010. In 2012, worldwide oil consumption increased by 1.3 million barrels per day (b/d) and forecasted to increase by 1.5 million b/d in 2013 (Radler, 2012). At the end of 2011, world proved oil reserves reached 1652.6 billion barrels which is sufficient to meet 54.2 years of global production. Asia Pacific founded about 41.3 thousand million barrels of oil reserves, in which 5.9 million barrels was constituted by Malaysia (BP, 2012).

Figure 1.1 shows the oil production and consumption in Malaysia from the year of 2001 to 2011. There was a peak production in Malaysia during 2004 which is about 762 thousand b/d and followed by drastic decrease in the succeeding years. In 2011, the oil production had a drop of about 10.9%. However, the oil consumption increased continuously with the growth of 0.7%. This is due to the energy use is the most essential requirement for human existence. It is indeed the livewire of industrial,

food and agricultural manufacture, the fuel for transportation as well as for the electricity generation in conventional thermal power plants. The world would hit a limit on the amount of oil could be extracted from the ground. According to Kuhlman (2007), oil is now being consumed at a rate of four times faster than it is being discovered, and thus the circumstances is becoming critical.

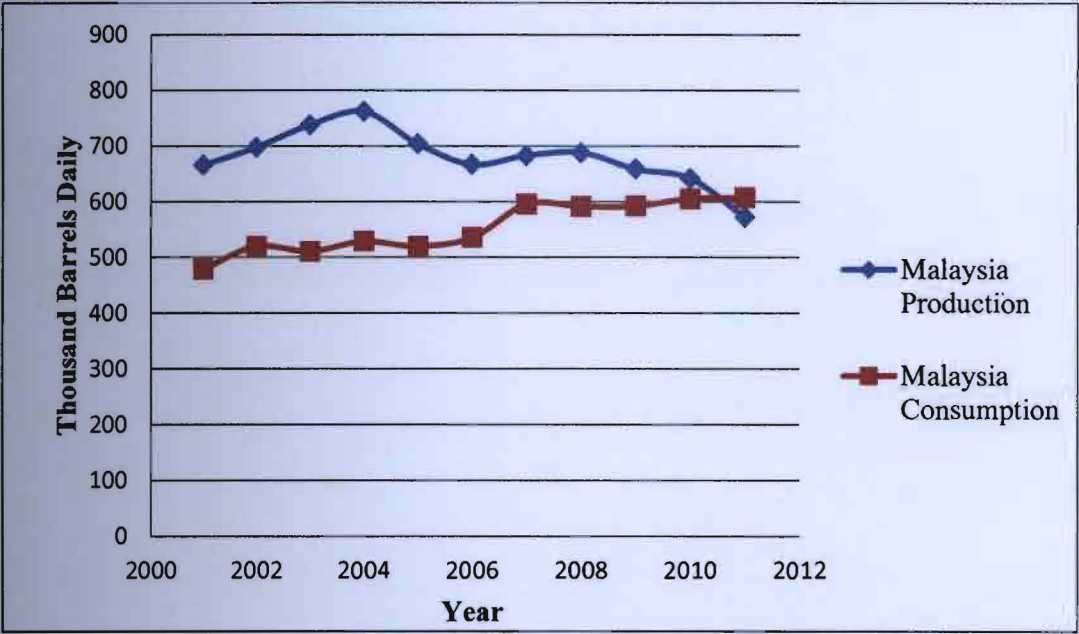


Figure 1.1: Oil production and consumption trend in Malaysia (BP, 2012)

1.2 Problem Statement

The globe is threatened with the twin catastrophes of fossil fuel depletion and environmental degradation. The excessively extraction and consumption of fossil fuels have caused a severe reduction in petroleum reserves. Furthermore, the petroleum based fuels including gasoline, jet fuel, kerosene, and diesel are attained from limited reserves. The world is no longer granted with new sources of economical fossil fuels and professionals have warned about the exhaustion of the